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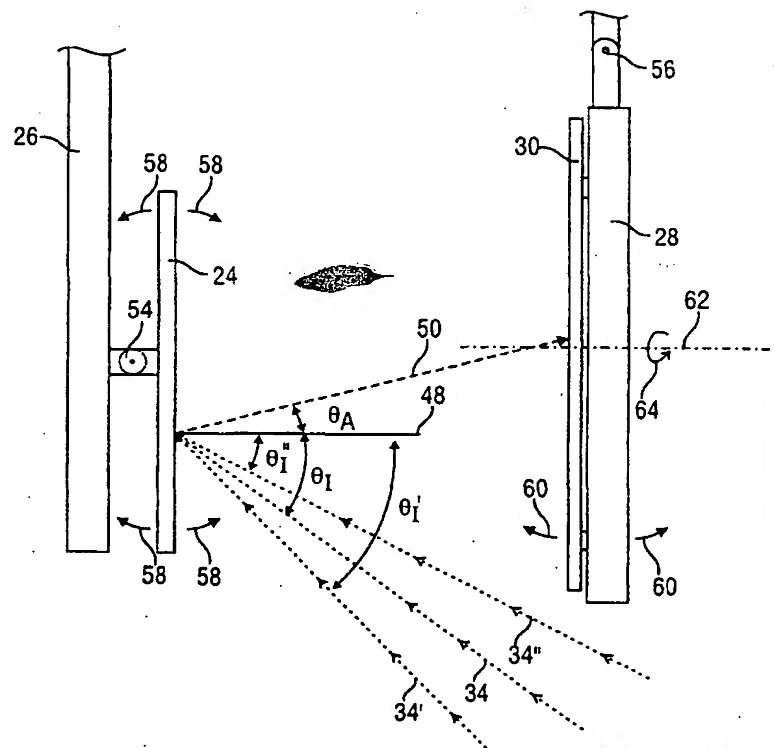
(54) Title: METHOD AND APPARATUS FOR DIRECTIONAL DEPOSITION OF THIN FILMS USING LASER ABLATION

(57) Abstract

A method and apparatus for laser ablation deposition of materials onto a substrate (30). The disclosed method and apparatus facilitate the deposition of thin films of a target material (24) onto a substrate (30) having features of high aspect ratio, e.g., an aspect ratio greater than one. In one embodiment, a laser ablation apparatus is provided in which the target support and substrate (wafer) support are independently angularly adjustable (54, 56), such that the angle (θ_A) at which material ablated from the target (24) is deposited onto the substrate (30) can be adjusted and controlled. Uniformity of deposited layers may be further enhanced by moving (e.g., rotating or raster scanning) the target (24) with respect to the laser and/or by moving (e.g., rotating or raster scanning) the substrate (30) with respect to the target (24).



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METHOD AND APPARATUS FOR DIRECTIONAL DEPOSITION OF THIN FILMS USING LASER ABLATION

FIELD OF THE INVENTION

This invention relates generally to the field of thin film deposition, and more particularly relates to the use of laser ablation techniques for thin film deposition.

BACKGROUND OF THE INVENTION

A number of techniques are known and used for making reproducible high-quality thin films, including sputtering, thermal and electronic beam evaporation, molecular beam deposition, and laser deposition. Thin film deposition is commonly performed in semiconductor device fabrication. In this context, thin film deposition involves coating a material onto a semiconductor substrate (e.g., a silicon wafer or die).

There are a number of considerations associated with thin film deposition which can be determinative or suggestive of the preferable deposition technique used for a given application. For example, the type of material to be applied may be better suited to one technique over another. Also, some techniques are generally regarded as more effective than others at coating a material in stoichiometrically identical form, i.e., without change in the composition of the applied material. The temperature and pressure requirements of a given thin-film deposition technique must also be taken into account.

Another consideration relates to the nature of the substrate onto which a thin film is to be deposited. The size and surface topology of the substrate in particular are of concern.

One difficulty which has manifested itself in connection with thin film deposition onto semiconductor substrates relates to topological features of the substrate which have what

shall be referred to herein as relatively high depth-to-width aspect ratios, i.e., features that are relatively deep and relatively narrow. (As used herein, the term aspect ratio will refer to the ratio depth/width, so that, for example, a feature 1μ deep and 1μ wide would have an aspect ratio of 1, a feature 2μ deep and 1μ wide would have an aspect ratio of 2, and so on.) One example of a high aspect ratio structure is the contact cavity formed for the so-called "trench capacitor" type of dynamic random-access memory (DRAM) devices. The problem with thin-film deposition in such structures is that it can be difficult to achieve sufficient coverage of the deposited material on the bottom and on the sides thereof. Using known techniques, coverage at the bottom of a deep structure may be as low as 10% or less of the coverage of exposed surfaces.

As those of ordinary skill in the semiconductor art will appreciate, the problem of uniform coverage of deep recesses or contacts is exacerbated as semiconductor devices shrink in size. For example, as a DRAM device design shrinks, the contacts must be narrower and deeper so as to minimize surface real estate. However, the height of a stack capacitor does not decrease, since the capacitance needs to be maximized.

It is believed that techniques which have a relatively highly collimated pattern of dispersal of the applied material are especially effective in achieving uniform coverage of a topographically complex substrate having high aspect ratio features. Collimated sputtering and laser ablation are two types of thin film deposition techniques which have at least some degree of collimated dispersion.

The forward emission profile (i.e., the extent of collimation of the dispersion pattern) for conventional magnetron sputtering is generally characterized as being proportional to

cos(θ) (where θ is the angle of incidence of the applied material to the substrate). The use of single collimators (circular, hexagonal, or square) can increase the emission profile to perhaps $\cos^2(\theta)$.

The forward emission profile for laser ablation, on the other hand, can be on the order of $\cos^{10}(\theta)$. This implies that the applied material is extremely forward directed and hence should be better able to reach the bottom of high aspect ratio structures more readily than even with collimated sputtering. Also, laser ablation is known to have superior contamination and stoichiometric control, and the formation of cusp or overhang near the top of a high-aspect ratio cavity is minimized due to the low pressure in a laser ablation chamber (typically 10^{-6} torr) as compared, for example, with sputtering (typically 10^{-3} torr).

Various laser ablation techniques have been known and practiced in the prior art. See, for example, Klein et al., "Small-Scale Laser Effects Experiments on Graphite: Coupling Coefficient, Lateral Loss, and Effective Heat of Ablation," *J. App. Phys.*, vol. 61, no. 5, March 1, 1987, pp. 1701 0 1712; Venkatesan et al., "Observation of Two Distinct Components During Pulsed Laser Deposition of High T_c Superconducting Films," *App. Phys. Lett.*, vol. 52, no. 14, April 4 1988, pp. 1193 - 1195; Neifeld et al., "Systematics of Thin Films Formed by Excimer Laser Ablation: Results on $SmBa_2Cu_3O_7$," *Appl. Phys. Lett.*, vol. 53, no. 8, August 22, 1988, pp. 703 - 704; and Greer, "Comparison of Large-Area Pulsed Laser Deposition Approaches," *SPIE Vol. 1835 Excimer Lasers* (1992), pp. 21 - 30.

In U.S. Patent No. 5,084,300 to Zander et al., entitled "Apparatus for Ablation of Material From A Target and Coating Method and Apparatus," there is proposed an ablation system in which the target from which material is ablated is cylindrical. The cylindrical target

is rotated about its central axis, and also moved longitudinally along this axis, in order to minimize the cratering of the target that can result if the laser is aimed at the same location for a prolonged period of time. According to the Zander et al. reference, this may enhance the uniformity and homogeneity of the resulting thin film layer.

The above-referenced Greer reference discusses various techniques for improving the uniformity of laser-ablated thin films. One technique is to rotate or laterally translate the substrate during the deposition process. Another involves scanning or "rastering" the laser beam at a large-area target.

While the prior art, as exemplified by the aforementioned Zander et al. and Greer references, has addressed the issue of uniformity of laser-deposited thin films, it is believed that there nonetheless remains room for improvement in the field of ablative deposition, particularly with regard to the deposition of thin films on high aspect ratio structures.

SUMMARY OF THE INVENTION

In view of the foregoing considerations, the present invention is directed to an improved method and apparatus for performing ablative deposition of materials onto a substrate.

In accordance with one aspect of the invention, means are provided for adjusting and controlling the angular positioning of either the ablation target (referred to herein as the "target substrate") or the substrate onto which target material is to be deposited (referred to herein as the "substrate"), or both, such that uniformity and step coverage of the ablated film are enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other aspects of the present invention may perhaps be best appreciated with reference to a detailed description of a specific embodiment of the invention, when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a simplified schematic diagram of a laser ablation apparatus in accordance with one embodiment of the invention;

Figure 2a illustrates a high-aspect ratio feature on a substrate onto which a thin film is to be deposited;

Figure 2b illustrates the feature of Figure 2a having a thin film ablatively deposited thereon using prior art techniques;

Figure 2c illustrates the feature of Figure 2a having a thin film ablatively deposited thereon using a method and apparatus in accordance with one embodiment of the invention; and

Figure 3 depicts the target substrate and substrate from the apparatus of Figure 1.

DETAILED DESCRIPTION OF A SPECIFIC EMBODIMENT OF THE INVENTION

Figure 1 is a schematic diagram of a representative laser ablation processing apparatus 10 for performing laser ablation deposition in accordance with one embodiment of the invention. Apparatus 10 includes a sealed processing chamber 12 which, as shown schematically in Figure 1 is coupled to a vacuum source 14. Chamber 12 may also be provided with a gas inlet 16 for facilitating the introduction of various reactive gases therein.

Various measurement devices, such as an ionization gauge 18, a spectrometer 20, and a thermocouple 22, may also be provided for monitoring various processing parameters during semiconductor processing.

Laser ablation deposition in accordance with the presently disclosed embodiment involves the use of one or more targets 24 supported within chamber 12 by means of a target substrate holder 26. In addition, a substrate heater and holder 28 is provided for supporting a substrate 30 (e.g., a semiconductor wafer) onto which material ablated from target(s) 24 is to be deposited.

Chamber 12 is preferably provided with a window 32 (e.g., a quartz window) for allowing a laser light beam 34 to be directed into chamber 12 toward target(s) 24. Laser light beam 34 is sufficient to produce a required intensity (in Joules/cm^2) at target(s) 24 to ablate the target material. The target material is then forward-ablated onto substrate 30 in a desired pattern.

It is believed that the present invention may be advantageously practiced using any type of laser, such as the conventionally known CO_2, xenon-chlorine, xenon-fluoride, or excimer lasers. In addition, it is believed that the present invention may be advantageously practiced in connection with the ablative deposition of many different types of target materials, including but by no means limited to titanium nitride, titanium, tungsten, aluminum, polysilicon, silicon nitride, and silicon dioxide.

As noted in the Background of the Invention section above, the present invention is concerned in particular with the deposition of materials, using laser ablation techniques, onto substrates (wafers) having relatively high aspect ratio features formed thereon. Figure 2a

illustrates one such high aspect ratio feature. In particular, Figure 2a shows a relatively deep and narrow trench 40 extending down beneath the surface 42 of substrate 30. In the illustrative embodiment, trench 40 may have dimensions of, for example, 2.0μ (depth) by 0.5μ (width), i.e., an aspect ratio of 4.

As also noted above, there are several potential disadvantages of prior art deposition techniques when applied to substrates having high aspect ratio features. These can perhaps be best appreciated with reference to Figure 2b, which shows substrate 30 having a layer of material 44 deposited thereon using prior art deposition techniques, for example, by collimated sputtering. Figure 2b shows several potential drawbacks to prior art deposition techniques. First, in many cases it may be difficult to achieve coverage at the bottom of trench 40 comparable to the coverage at the surface of substrate 30. In the illustrative example of Figure 2b, the surface coverage may be on the order of 1000 Angstroms, while coverage of only 100 Angstroms is achieved at the bottom of trench 40. There may similarly be a disparity between coverage on respective left and right side walls of trench 40. Also, some prior art deposition techniques may be susceptible to formation of overhangs or cusps 46 at the mouth of trench 40.

In contrast to Figure 2b, it is believed to be desirable to achieve a more uniform thin film coverage and step coverage of substrates having high aspect ratio features therein or thereon, as depicted in Figure 2c. In the prior art, several approaches have been taken to achieve the goal of uniform coverage on substrates; however, none of these techniques are believed to have addressed the issue of uniformity of step coverage, particularly on substrates having high aspect ratio features therein or thereon. First, it has been proposed to rotate or

otherwise move target(s) 24 in order to achieve uniform erosion thereof. Alternatively, or in addition, it has been proposed to move (e.g., raster scan) laser beam 34 across target(s) 24. This is believed also to enhance the uniformity of target erosion. Finally, it has also been proposed in the prior art to rotate or otherwise move substrate 30, also to promote uniformity of deposition. See, e.g., the above-cited Greer reference.

Figure 3 is a simplified diagram showing target 24 supported by target substrate holder 26 and substrate 30 supported by substrate holder 28 in the presently disclosed embodiment. As already described, laser ablation involves directing laser beam 34 toward target 24 and melting or ablating the target substrate, so that the material from which target 24 is composed is ablatively deposited onto substrate 30.

In Figure 3, laser beam 34 is shown impinging upon target 24 at an incident angle θ_I (line 48 in Figure 3 is perpendicular to the surface of target 24). Dashed line 50 in Figure 3 represents the path of ablated material as it travels from target 24 to substrate 30. In Figure 3, the ablated material is shown to leave target 24 at an ablation angle of θ_A.

It is believed that for laser ablation, the ablation angle θ_A is essentially-independent from the angle of incidence θ_I of laser beam 34. That is, for different incident angles, such as θ_I' and θ_I'' corresponding to laser beam paths 34' and 34" in Figure 3, the ablation angle θ_A will be the same. (It is believed that θ_A may be zero degrees in some cases, notwithstanding the depiction of Figure 3, which shows a non-zero θ_A merely for the sake of generality.)

In view of these apparent characteristics of laser ablation, the present invention contemplates providing means for controlling the relative positions of target 24 and substrate 30 in order to promote uniform ablative deposition of high aspect ratio structures on substrate

30. To this end, it is contemplated that some type of rotational adjustability of target 24 and substrate 30 be provided; in Figure 3, this adjustability is schematically reflected by the presence of rotatable couplings 54 and 56. Couplings 54 and 56 enable target 24 to be adjusted in the direction of arrows 58, and substrate 30 to be adjusted in the direction of arrows 60. Rotational couplings 54 and 56 are also represented in the simplified diagram of Figure 1.

Of course, rotatable couplings 54 and 56 are shown in a very greatly simplified representation in Figure 3. It is contemplated that the relative angular adjustability of target 24 and substrate 30 can be accomplished in accordance with conventional vacuum chamber technology, for example, the adjustable mounting brackets, mounting tables and the like commonly employed for carrying out various known types of frontal lithography processes, such as so-called "angled implant" procedures and the like.

Given the angular adjustability of target 24 and substrate 30 (or at least the angular adjustability of either target 24 with respect to substrate 30 or vice versa), then for a given ablation procedure, the ablation angle θ_A can be determined without undue experimentation by a person of ordinary skill in the art. Then, the appropriate relative angular positioning of target 24 and substrate 30 can be established, through adjustment of the substrate supports 26 and 28 in accordance with conventional practice in the art, to achieve the desired coverage. For example, if optimal step coverage of high aspect ratio structures is desired, it will likely be desirable to ensure that the ablation angle θ_A be accounted for (i.e., by adjusting the angular position of target 24 and/or substrate 30) such that ablated material is directed perpendicularly to substrate 30.

Although the presently disclosed embodiment of the invention has thus far been described in terms of adjusting the angular positioning of target 24 and substrate 30, the present invention can alternatively be accurately described in terms of merely controlling the relative angular positions of target 24 and substrate 30. That is, angular adjustability of both target 24 and substrate 30 may not be necessary for the purposes of practicing the present invention. It is contemplated that control of the angular positioning substrate 30 alone may be all that is necessary.

On the other hand, although it is believed that in some cases the ablation angle θ_A is independent from the angle of incidence θ_I of laser beam 34, this may not always be true. In that case, rotational coupling 54 would facilitate adjustment of θ_I to achieve a given θ_A. Then, adjustment of rotational coupling 56 would facilitate achieving the desired angle of deposition of ablated material, e.g., perpendicular to the surface of substrate 30.

In one embodiment of the invention, substrate 30 is further rotatably adjustable about a central axis, designated with reference numeral 62 in Figure 3, such that substrate 30 can be rotated as indicated by arrow 64. Such adjustability can facilitate achieving more uniform sidewall coverage, in various structures, including cylindrical ones.

Given the adjustability of target 24 and substrate 30, it is believed that many different types of control can be exercised over the ablation deposition procedure. For example, uniform step coverage, as discussed above with reference to Figure 2c, can be achieved. Alternatively, it may be desirable to control sidewall coverage or sidewall dispersal using the principles of the present invention.

In addition, although certain advantages of the present invention have been discussed herein in the context of enhanced step coverage of cylindrical high-aspect ratio structures present on a semiconductor substrate, it will be appreciated by those of ordinary skill in the art that the present invention may find applicability in connection with many types of high-aspect ratio features. The invention will have particular applicability any-time it is desired to have a uniform deposition coating on all of the surfaces of high-aspect ratio structures.. Examples include formation of barrier layers, formation of capacitors and diodes, and in many other situations familiar to those of ordinary skill in the art where a defect in a deposited layer could lead to shorting, punch-through, and failure.

In view of the foregoing, it should be apparent that a method and apparatus for laser ablation deposition has been disclosed. In accordance with one aspect of the invention, a method and apparatus has been disclosed in which step coverage uniformity of the layer deposited onto high-aspect ratio structures is enhanced through adjustment and control of the relative angular positioning of the target substrate and substrate.

Although a specific embodiment of the invention has been described herein in some detail, this has been done only for the purposes of illustrating various aspects of the invention. It is believed that many substitutions, alterations, and/or modifications, including but not limited to those specifically discussed herein, may be made to the disclosed embodiment without departing from the spirit and scope of the invention as defined in the appended claims, which follow.

CLAIMS:

1. A method of thin-film deposition, comprising steps of:

(a) supporting a target from which target material is to be ablated in path of a laser beam, such that said target material is ablated off of said target at an ablation angle θ_A with respect to said target;

(b) supporting a substrate onto which said target material is to be deposited in a position such that said target material ablated from said target is directed toward said substrate said substrate having at least one high aspect ratio feature on a surface thereof;

(c) selecting a desired angle at which said target material is to be directed toward said substrate;

(d) adjusting said substrate's position relative to said target such that said target material ablated from said target is directed toward said substrate at said desired angle such that said target material is deposited in a layer of uniform thickness over said substrate's surface including said at least one high aspect ratio feature.

2. The method of claim 1, wherein said step (d) of adjusting comprises adjusting said substrate's angular position relative to said target.

3. The method of claim 1, further comprising step (e) of raster scanning said laser beam over said target's surface.

4. The method of claim 1, further comprising step (e) of moving said target relative to said laser beam.

5. The method of claim 1, further comprising the step (e) of moving said substrate relative to said target.

6. The method of claim 1, further comprising steps:

(e) moving said target relative to said laser beam; and

(f) moving said substrate relative to said target.

7. The method of claim 1, further comprising steps:

(e) moving said laser beam relative to said target;

(f) moving said substrate relative to said target.

8. A method in accordance with claim 1, wherein said substrate having at least one high aspect ratio feature an aspect ratio greater than one.

9. A method in accordance with claim 1, wherein said desired angle is perpendicular to said substrate's surface.

10. A method in accordance with claim 1, wherein said step (d) of adjusting is performed during ablation of said target.

11. A method in accordance with any of claims 4, 5, 6, or 7, wherein said step (e) of moving is performed during ablation of said target.

12. An apparatus for depositing a target material onto a substrate, comprising:

a target support for supporting a target composed of target material to be deposited;

a substrate support for supporting said substrate in an angular position with respect to said target;

a laser, for generating a laser beam directed at said target, said laser beam impinging on said target and ablating material from said target;

wherein said substrate support is disposed so as to place said substrate in the path of said material ablated from said target;

and wherein said substrate support is angularly adjustable such that said angular position is adjustable.

13. An apparatus in accordance with claim 12, wherein said target support is angularly adjustable such that said fixed angular position is adjustable.

14. An apparatus in accordance with claim 12, wherein said target support and said substrate support are housed within a vacuum chamber.

15. An apparatus in accordance with claim 12, wherein said target support is movable with respect to said laser beam.

16. An apparatus in accordance with claim 12, wherein said substrate support is movable with respect to said target.

17. An apparatus in accordance with claim 12, wherein said laser beam moves with respect to said target.

18. An apparatus in accordance with claim 12, wherein:
said target support is movable with respect to said laser beam;
said substrate support is movable with respect to said target;
and said target support is angularly adjustable such that said angular position is adjustable.

19. An apparatus in accordance with claim 12, wherein said substrate has features having an aspect ratio greater than one.

20. A method of depositing a target material onto a semiconductor wafer comprising a substrate having features having an aspect ratio greater than one thereon, [illegible]rising steps of:
(a) supporting a target from which target material is to be ablated in the path of a laser beam, such that said target material is ablated off of said target at an ablation angle θ_A with respect to said target;
(b) supporting said wafer in a position such that said target material ablated from said target is directed toward said substrate;
(c) selecting a desired angle at which said target material is to be directed toward said substrate;
(d) adjusting said wafer's position relative to said target such that said target material ablated from said target is directed toward said wafer at said desired angle.

21. The method of claim 20, wherein said step (d) of adjusting comprises adjusting the angular position of said wafer relative to said target.

22. The method of claim 20, further comprising step (e) of raster scanning said laser beam over said target's surface.

23. The method of claim 20, further comprising step (e) of moving said target relative to said laser beam.

24. The method of claim 20, further comprising step (e) of moving said wafer relative to said target.

25. The method of claim 20, further comprising steps:

(e) moving said target relative to said laser beam; and

(f) moving said wafer relative to said target.

26. The method of claim 20, further comprising steps:

(e) moving said laser beam relative to said target;

(f) moving said wafer relative to said target.

27. A method in accordance with claim 20, wherein said desired angle is perpendicular to said wafer's surface.

28. A method in accordance with claim 20, wherein said step (d) of adjusting is performed during ablation of said target.

29. A method of depositing a film on a substrate, comprising steps of:

(a) providing a target;

(b) impinging said target with a laser beam;

(c) supporting said substrate in a spaced relation to said target; and

(d) adjusting a relative angular relation between said substrate and said target.

30. A method in accordance with claim 29, wherein said substrate is moved to adjust the angular relation between the target and the substrate.

31. A method in accordance with claim 29. wherein said angular relation is adjusted while said target is impinged by said laser beam.

32. An apparatus for depositing a target material onto a substrate, comprising:

a target support configured to support a target comprising a material to be deposited;

a substrate support configured to support said substrate in a desired angular relation to said target;

a laser assembly configured to generate a laser beam directed at said target, said laser oriented to direct a beam to impinge said target to ablate material from said target, said substrate support located to place said substrate in the path of said ablated material;

wherein said substrate support is operable to angularly adjust the position of said substrate relative to said target.

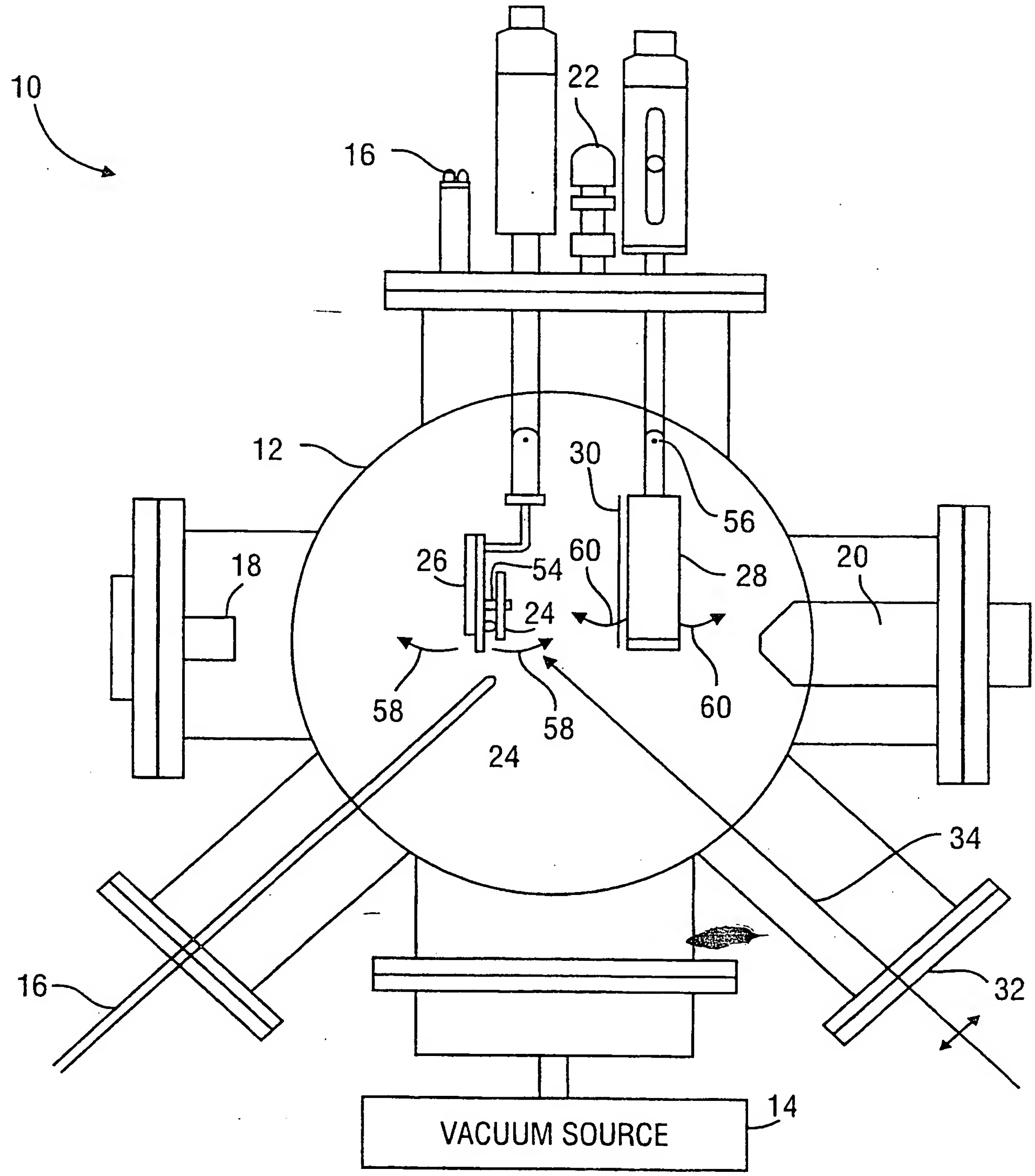
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Figure 1

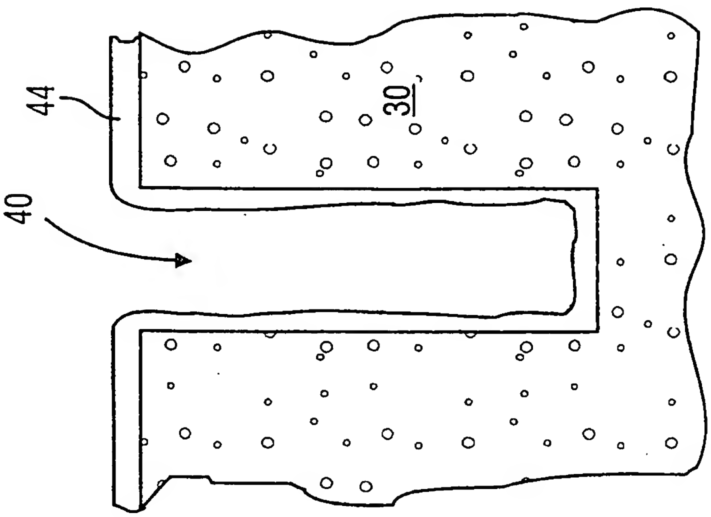

Figure 2C

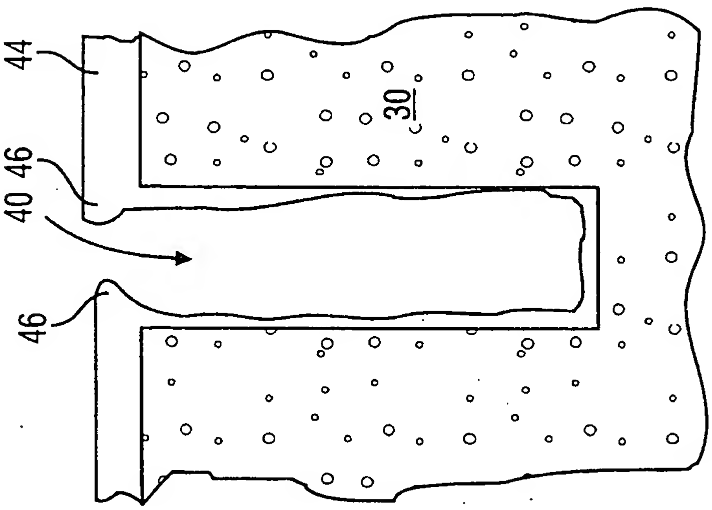

Figure 2B

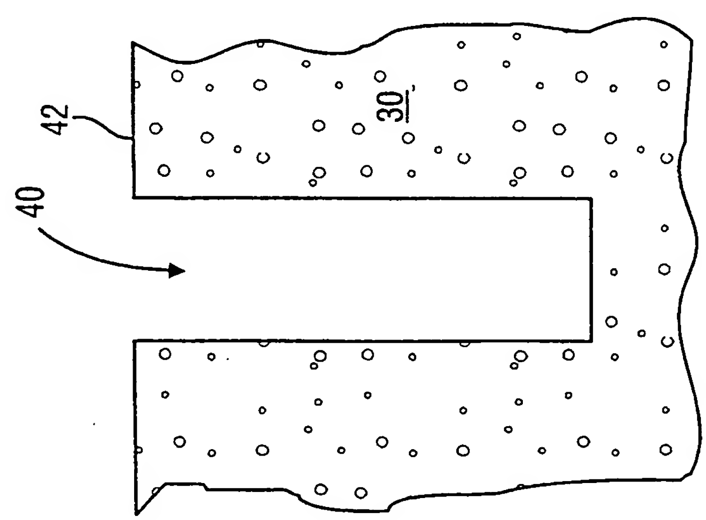

Figure 2A

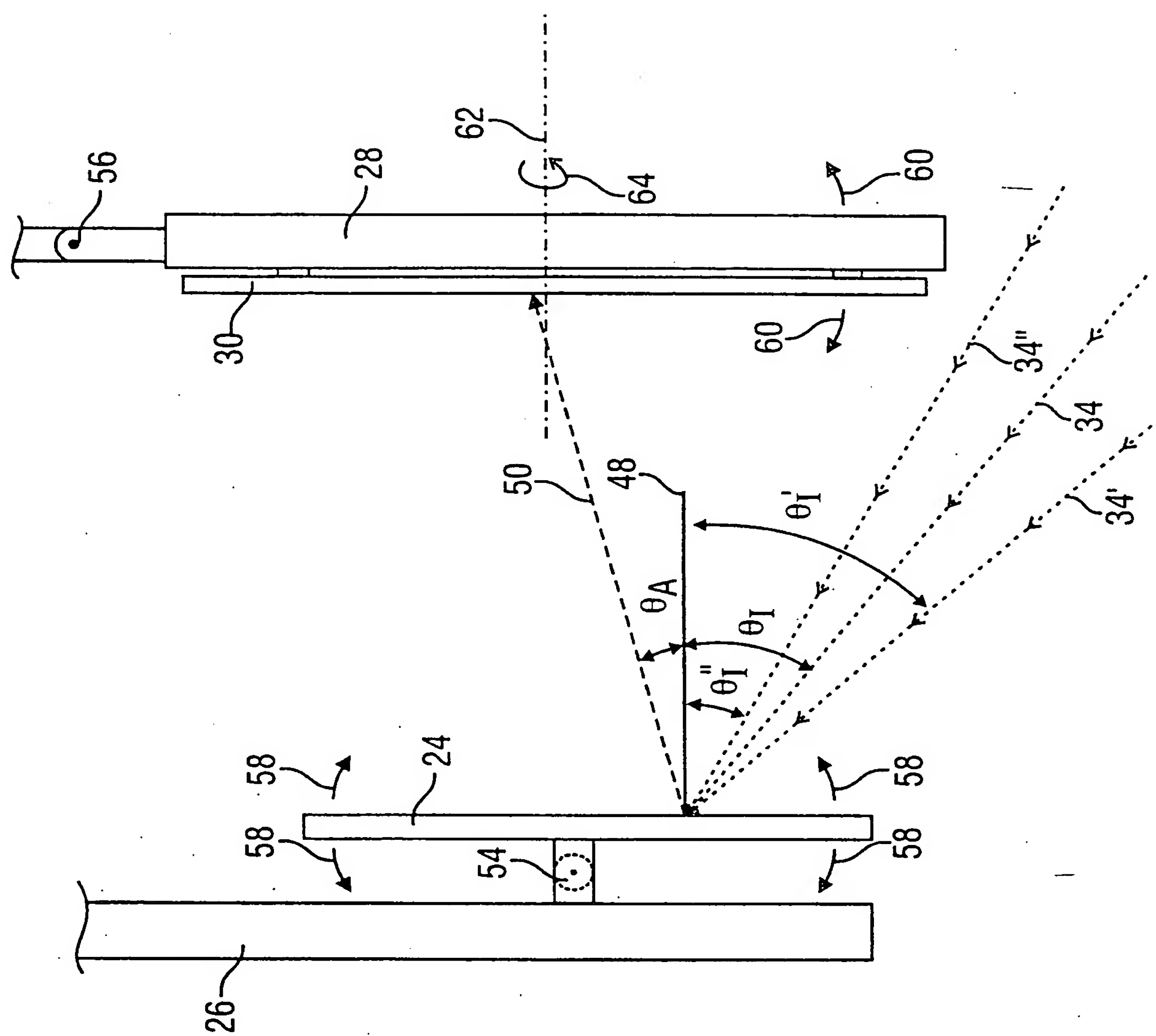
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Figure 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/20731

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C23C14/28 C23C14/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	PATENT ABSTRACTS OF JAPAN vol. 096, no. 004, 30 April 1996 & JP 07 331423 A (HITACHI LTD), 19 December 1995, see abstract ---	1,3-11, 20,22-28 2,21
X	GB 2 272 912 A (MITSUBISHI ELECTRIC CORP) 1 June 1994 see figure 116 ---	12-19, 29-32
Y	PHAM T T ET AL: "BEAM STEERING LASER ASSISTED DEPOSITION SYSTEM FOR HIGH-TC SUPERCONDUCTING THIN FILM DEVICES" JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY: PART A, vol. 9, no. 2, 1 March 1991, pages 271-273, XP000237666 see paragraph 2; figure 3 --- -/--	2,21

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
10 March 1998	17/03/1998

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 435 801 A (IBM) 3 July 1991 see page 5, line 19 - line 37; claim 1 -----	1-32

1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 97/20731

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2272912 A	01-06-94	JP 6172981 A	21-06-94
		DE 4340752 A	01-06-94
		GB 2303379 A,B	19-02-97
		GB 2300000 A	23-10-96
		GB 2300426 A,B	06-11-96
		GB 2300001 A,B	23-10-96
		US 5622567 A	22-04-97
EP 0435801 A	03-07-91	JP 3191055 A	21-08-91
		US 5246885 A	21-09-93